01170/00076

SPECIFICATION

TO ALL WHOM IT MAY CONCERN:

Be it known that I, ROBERT C. LAM, a citizen of the United States, resident of Rochester, County of Oakland, State of Michigan have invented a new and useful improvement in an

ELASTIC AND POROUS FRICTION MATERIAL WITH HIGH AMOUNT OF FIBERS

which invention is fully set forth in the following specification.

DESCRIPTION

ELASTIC AND POROUS FRICTION MATERIAL WITH HIGH AMOUNT OF FIBERS

TECHNICAL FIELD

The present invention relates to an elastic and porous fiction material having a high amount of fibers. The friction material of the present invention has high coefficient of friction characteristics, high-energy durability, and extremely high heat, or "hot spot" resistance. The friction material also has improved strength, wear resistance and noise resistance.

BACKGROUND ART

New and advanced continuous torque transmission systems, having continuous slip torque converters and shifting clutch systems are being developed by the automotive Industry. These new systems often Involve high energy requirements. Therefore, the friction materials technology must be also developed to meet the increasing energy requirements of these advanced systems.

In particular, a new high performance, durable friction material is needed. The new friction material must be able to withstand high speeds wherein surface speeds are up to about 65m/seconds. Also, the friction material must be able to withstand high facing lining pressures up to about 1500 psi. It is also important that the friction material be useful under limited lubrication conditions.

The friction material must be durable and have high heat resistance in order to be useful in the advanced systems. Not only must the friction material remain stable at high temperatures, it must also be able to rapidly dissipate the high heat that is being generated during operating conditions.

The high speeds generated during engagement and disengagement of the new systems mean that a friction material must be able to maintain a relatively constant friction throughout the engagement. It is important that the

frictional engagement be relatively constant over a wide range of speeds and temperatures in order to minimize "shuddering" of materials during braking or the transmission system during power shift from one gear to another. It is also important that the friction material have a desired torque curve shape so that during frictional engagement the friction material is noise or "squawk" free.

In particular, transmission and torque-on-demand systems incorporate slipping clutches mainly for the fuel efficiency and driving comfort. The role of the slip clutch within these systems varies from vehicle launching devices, such as wet start clutches, to that of a torque converter clutches. According to the operating conditions, the slip clutch can be differentiated into three principle classes: (1) Low Pressure and High Slip Speed Clutch, such as wet start clutch; (2) High Pressure and Low Slip Speed Clutch, such as Converter Clutch; and (3) Extreme Low Pressure and Low Slip Speed Clutch, such as neutral to idle clutch.

The principal performance concerns for all applications of the slip clutch are the prevention of shudder and the energy management of the friction interface. The occurrence of shudder can be attributed to many factors including the friction characteristics of the friction material, the mating surface's hardness and roughness, oil film retention, lubricant chemistry and interactions, clutch operating conditions, driveline assembly and hardware alignment, and driveline contamination. The friction interface energy management is primarily concerned with controlling interface temperature and is affected by the pump capacity, oil flow path and control strategy. The friction material surface design also contributes to the efficiency of interface energy management.

Previously, asbestos fibers were included in the friction material for temperature stability. Due to health and environmental problems, asbestos is no longer being used. More recent friction materials have attempted to overcome the absence of the asbestos in the friction material by modifying impregnating paper or fiber materials with phenolic or phenolic-modified resins. These friction materials, however, do not rapidly dissipate the high heat generated, and do not have the necessary heat resistance and satisfactory

high coefficient of friction performance now needed for use in the high speed systems currently being developed.

The Kearsey U.S. Patent No. 5,585,166 describes a multi layer friction lining having a porous substrate layer (cellulose and synthetic fibers, filler and thermoset resin) and a porous friction layer (nonwoven synthetic fibers in a thermoset resin) where the friction layer has a higher porosity than the substrate layer.

The Seiz U.S. Patent No. 5,083,650 reference involves a multi-step impregnating and curing process; i.e., a paper impregnated with a coating composition, carbon particles are placed on the paper, the coating composition in the paper is partially cured, a second coating composition is applied to the partially cured paper, and finally, both coating compositions are cured.

In other friction materials, metallic fibers combined with carbon materials were included in the friction material for wear resistance. For example, Fujimaki et al. U.S. Patent No. 4,451,590 describes a friction material having metallic fibers, filler, carbon particles, carbon fibers and phenolic resin. However, the metallic based friction materials do not have sufficient porosity and compressibility to be capable of high fluid permeation capacity during use. Also, the metallic based friction materials are not sufficiently resilient or elastic, yet resistant to compression set to be capable of withstanding high facing lining pressures of up to about 1500 psi (approximately 105 kg/cm^2). The metallic based friction material also is not capable of withstanding high surface speeds of up to about 65 m/second which are generated during engagement and disengagement of the new transmission and braking systems.

Various paper based fibrous materials have been developed that are co-owned by the assignee herein, BorgWarner Inc., for use in friction materials. These references are fully incorporated herein by reference.

In particular, Lam et al., U.S. Patent No. 5,998,307 relates to a friction material having a primary fibrous base material impregnated with a curable resin where the porous primary layer comprises at least one fibrous material and a secondary layer comprises carbon particles covering at least about 3 to about 90% of the surface of the primary layer.

The Lam et al., U.S. Patent No. 5,858,883 relates to a base material having a primary layer of less fibrillated aramid fibers, synthetic graphite, and a filler, and a secondary layer comprising carbon particles on the surface of the primary layer.

The Lam et al., U.S. Patent No. 5,856,244 relates to a friction material comprising a base impregnated with a curable resin. The primary layer comprises less fibrillated aramid fibers, synthetic graphite and filler; the secondary layer comprises carbon particles and a retention aid.

The Lam et al. U.S. Patent No. 5,958,507 relates to a process for producing a friction material where about 3 to about 90% of at least one surface of the fibrous material which comprises less fibrillated aramid fibers is coated with carbon particles.

The Lam, U.S. Patent No. 6,001,750 relates to a friction material comprising a fibrous base material impregnated with a curable resin. The porous primarily layer comprises less fibrillated aramid fibers, carbon particles, carbon fibers, filler material, phenolic novoloid fibers, and optionally, cotton fibers. The secondary layer comprises carbon particles which cover the surface at about 3 to about 90% of the surface.

Yet another commonly owned patent application, Serial No. 09/707,274, now allowed, relates to a paper type friction material having a porous primary fibrous base layer with friction modifying particles covering about 3 to about 90% of the surface area of the primary layer.

In addition, various paper type fibrous base materials are described in commonly owned BorgWarner Inc. Lam et al., U.S. Patent Nos. 5,753,356 and 5,707,905 which describe base materials comprising less fibrillated aramid fibers, synthetic graphite and filler, which references are also fully incorporated herein by reference.

Another commonly owned patent, the Lam, U.S. Patent No. 6,130,176, relates to non-metallic paper type fibrous base materials comprising less fibrillated aramid fibers, carbon fibers, carbon particles and filler.

For all types of friction materials, in order to be useful in "wet" applications, the friction material must have a wide variety of acceptable

characteristics. The friction material must have good anti-shudder characteristics; have high heat resistance and be able to dissipate heat quickly; and, have long lasting, stable and consistent frictional performance. If any of these characteristics are not met, optimum performance of the friction material is not achieved.

It is also important that a suitable impregnating resin be used in the friction material in order to form a high energy application friction material. The friction material must have good shear strength during use when the friction material is infused with brake fluid or transmission oil during use.

It is also important, under certain applications, that the friction materials have high porosity such that there is a high fluid permeation capacity during use. Thus, it is important that the friction material not only be porous, it must also be compressible. The fluids permeated into the friction material must be capable of being squeezed or released from the friction material quickly under the pressures applied during operation of the brake or transmission, yet the friction material must not collapse. It is also important that the friction material have high thermal conductivity to also help rapidly dissipate the heat generated during operation of the brake or transmission.

As far as is known, there is no disclosure of friction material for use in transmission systems which includes a fibrous base material comprising a high fiber content/low filler content fibrous base material.

Accordingly, it is an object of the present invention to provide an improved friction material with reliable and improved properties compared to those of the prior art.

A further object of this invention is to provide a friction materials with improved "anti-shudder", "hot spot" resistance, high heat resistance, high friction stability and durability, and strength.

IN THE DRAWINGS

Fig. 1 is a schematic diagram showing a friction material having a high fiber content fibrous base material.

SUMMARYOF THE INVENTION

The present invention relates to a friction that comprises a high amount of fibers in a fibrous base material.

In certain preferred embodiments, the fibrous base material comprises about 75% to about 85%, and in certain embodiments, about 80%, by weight, fibers, based on the weight of the fibrous base material. The remainder of the fibrous base material comprises other ingredients including fillers, friction material and the like which preferably comprise about 15 to about 25%, an in certain embodiments, about 20%, by weight, of the fibrous base

DETAILED DESCRIPTION OF INVENTION

In order to achieve the requirements discussed above, many friction materials were evaluated for friction and heat resistant characteristics under conditions similar to those encountered during operation. Commercially available friction materials were investigated and proved not to be suitable for use in high energy applications.

According to the present invention, a friction material has a uniform dispersion of the curable resin throughout a high fiber content fibrous base material. The high fiber content friction material is more elastic and porous than conventional paper friction materials.

Various fibrous base materials are useful in the friction material of the present invention, including, for example, non-asbestos fibrous base materials comprising, for example, fabric materials, woven and/or nonwoven materials. Suitable fibrous base materials include, for example, fibers and fillers. The fibers can be organic fibers, inorganic fibers and carbon fibers. The organic fibers can be aramid fibers, such as fibrillated and/or nonfibrillated aramid fibers, acrylic fibers, polyester fibers, nylon fibers, polyamide fibers, cotton/cellulose fibers and the like. The fillers can be, for example, silica, diatomaceous earth, graphite, alumina, cashew dust and the like.

In other embodiments, the fibrous base material can comprise fibrous woven materials, fibrous non-woven materials, and paper materials. Further, examples of the various types of fibrous base materials useful in the present

invention are disclosed in the above-referenced BorgWarner U.S. patents which are fully incorporated herein by reference. It should be understood however, that other embodiments of the present invention can include yet different fibrous base materials.

In certain embodiments, the friction material comprises a fibrous base material which has a plurality of voids or interstices therein. The size of the voids in the fibrous base material can range from about 0.5 μm to about 20 μm.

In certain embodiments, the fibrous base material preferably has a void volume of about 50 to about 60% such that the fibrous base material is considered "dense" as compared to a "porous" woven material.

In certain embodiments, friction material further comprises a resin material which at least partially fills the voids in the fibrous base material. The resin material is substantially uniformly dispersed throughout the thickness of the fibrous base material.

In certain embodiments, the fibrous base material comprises a fibrous base material where less fibrillated fibers and carbon fibers are used in the fibrous base material to provide a desirable pore structure to the friction material. The fiber geometry not only provides increased thermal resistance, but also provides delamination resistance and squeal or noise resistance. Also, in certain embodiments, the presence of the carbon fibers and carbon particles aids in the fibrous base material in increasing the thermal resistance, maintaining a steady coefficient of friction and increasing the squeal resistance. A relatively low amount of cotton fibers in the fibrous base material can be included to improve the friction material's clutch "break-in" characteristics.

The use of less fibrillated aramid fibers and carbon fibers in a fibrous base material improves the friction material's ability to withstand high temperatures. Less fibrillated aramid fibers generally have few fibrils attached to a core fiber. The use of the less fibrillated aramid fibers provides a friction material having a more porous structure; i.e., there are larger pores than if a typical fibrillated aramid fiber is used. The porous structure is generally defined by the pore size and liquid permeability. In certain embodiments, the fibrous

base material defines pores ranging in mean average size from about 2.0 to about 25 microns in diameter, and in certain embodiments, from about 2 to about 10 microns. In certain embodiments, the mean pore size ranges from about 2.5 to about 8 microns, and in certain embodiments from about 5 to about 8 microns, in diameter and the friction material had readily available air voids of at least about 50% and, in certain embodiments, at least about 60% or higher.

Also, in certain embodiments, it is desired that the aramid fibers have a length ranging from about 0.5 to about 10 mm and a Canadian Standard Freeness (CSF) of greater than about 300. In certain embodiments, it is also desired to use less fibrillated aramid fibers which have a CSF of about 450 to about 550 preferably about 530 and greater; and, in other certain embodiments, about 580-650 and above and preferably about 650 and above. In contrast, more fibrillated fibers, such as aramid pulp, have a freeness of about 285-290.

The "Canadian Standard Freeness" (T227 om-85) means that the degree of fibrillation of fibers can be described as the measurement of freeness of the fibers. The CSF test is an empirical procedure which gives an arbitrary measure of the rate at which a suspension of three grams of fibers in one liter of water may be drained. Therefore, the less fibrillated aramid fibers have higher freeness or higher rate of drainage of fluid from the friction material than more fibrillated aramid fibers or pulp. Friction materials comprising the aramid fibers having a CSF ranging from about 430-650 (and in certain embodiments preferably about 580-640, or preferably about 620-640), provide superior friction performance and have better material properties than friction materials containing conventionally more fibrillated aramid fibers. The longer fiber length, together with the high Canadian freeness, provide a friction material with high strength, high porosity and good wear resistance. The less fibrillated aramid fibers (CSF about 530-about 650) have especially good long-term durability and stable coefficients of friction.

Various fillers are also useful in the fibrous base material of the present invention. In particular, silica fillers, such as diatomaceous earth, are useful.

However, it is contemplated that other types of fillers are suitable for use in the present invention and that the choice of filler depends on the particular requirements of the friction material.

In certain embodiments, cotton fiber is added to the fibrous base material of the present invention to give the fibrous material higher coefficients of friction. In certain embodiments, about 5 to about 20%, and, in certain embodiments, about 10% cotton can also be added to the fibrous base material.

One example of a formulation for the fibrous base material comprises about 75% to about 85%, by weight, of a less fibrillated aramid fiber; and, about 15% to about 25%, by weight of a filler material.

In certain other embodiments, one particular formulation has found to be useful comprises about 35 to about 45%, by weight, less fibrillated aramid fibers; about 5 to about 15% cotton fibers; about 2 to about 20%, by weight, carbon fibers; and, about 25 to about 35%, by weight, filler.

In still other embodiments, the base material comprises from about 15 to about 25% cotton, about 40 to about 50% aramid fibers, about 10 to about 20% carbon fibers, about 5 to about 15% filler such as celite, and, optionally about 1 to about 3% latex add-on.

When the fibrous base material has a higher mean pore diameter and fluid permeability, the friction material is more likely to run cooler or with less heat generated in a transmission due to better automatic transmission fluid flow throughout the porous structure of the friction material. During operation of a transmission system, the fluid tends, over time, to breakdown and form "oil deposits", especially at high temperatures. These "oil deposits" decrease the pore openings. Therefore, when the friction material initially starts with lager pores, there are more open pores remaining during the useful life of the friction material.

In certain embodiments, the fibrous base material can be impregnated using different resin systems. In certain embodiments, it is useful to use at least one phenolic resin, at least one modified phenolic-based resin, at least one silicone resin, at least one modified silicone resin, at least one epoxy resin,

at least one modified epoxy resin, and/or combinations of the above. In certain other embodiments, a silicone resin blended or mixed with a phenolic resin in compatible solvents is useful.

Various resins are useful in the present invention. In certain embodiments, the resin can comprise phenolic or phenolic based resins, preferably so that the saturant material comprises about 45 to about 65 parts, by weight, per 100 parts, by weight, of the friction material. After the resin mixture has been applied to the fibrous base material and the fibrous base material has been impregnated with the resin mixture, the impregnated fibrous base material is heated to a desired temperature for a predetermined length of time to form a friction material. In certain embodiments, the heating cures the phenolic resin present in the saturant at a temperature of about 300°F. When other resins are present in the saturant, such as a silicone resin, the heating cures the silicone resin at a temperature of about 400°F. Thereafter, the cured friction material is adhered to a desired substrate by suitable means.

Various useful resins include phenolic resins and phenolic-based resins. It is to be understood that various phenolic-based resins which include in the resin blend other modifying ingredients, such as epoxy, butadiene, silicone, tung oil, benzene, cashew nut oil and the like, are contemplated as being useful with the present invention. In the phenolic-modified resins, the phenolic resin is generally present at about 50% or greater by weight (excluding any solvents present) of the resin blend. However, it has been found that friction materials, in certain embodiments, can be improved when the mixture includes resin blend containing about 5 to about 80%, by weight, and for certain purposes, about 15 to about 55%, and in certain embodiments about 15 to about 25%, by weight, of silicone resin based on the weight of the silicone-phenolic mixture (excluding solvents and other processing acids).

Examples of useful phenolic and phenolic-silicone resins useful in the present invention are fully disclosed in the above-referenced BorgWarner U.S. patents which are fully incorporated herein, by reference. Silicone resins useful in the present invention include, for example, thermal curing silicone sealants

and silicone rubbers. Various silicone resins are useful with the present invention. One resin, in particular, comprises xylene and acetylacetone (2,4-pentanedione). The silicone resin has a boiling point of about 362°F (183°C), vapor pressure at 68°F mm. Hg: 21, vapor density (air=1) of 4.8, negligible solubility in water, specific gravity of about 1.09, percent volatile, by weight, 5% evaporation rate (ether=1), less than 0.1, flash point about 149°F (65°C) using the Pensky-Martens method. It is to be understood that other silicone resins can be utilized with the present invention. Other useful resin blends include, for example, a suitable phenolic resin comprises (% by wt.): about 55 to about 60% phenolic resin; about 20 to about 25% ethyl alcohol; about 10 to about 14% phenol; about 3 to about 4% methyl alcohol; about 0.3 to about 0.8% formaldehyde; and, about 10 to about 20% water. Another suitable phenolic-based resin comprises (% by wt.): about 50 to about 55% phenol/formaldehyde resin; about 0.5% formaldehyde; about 11% phenol; about 30 to about 35% isopropanol; and, about 1 to about 5% water.

It has also been found that another useful resin is an epoxy modified phenolic resin which contains about 5 to about 25 percent, by weight, and preferably about 10 to about 15 percent, by weight, of an epoxy compound with the remainder (excluding solvents and other processing aids) phenolic resin. The epoxy-phenolic resin compound provides, in certain embodiments, higher heat resistance to the friction material than the phenolic resin alone.

In certain embodiments, it is preferred that resin mixture comprises desired amounts of the resin and the friction modifying particles such that the target pick up of resin by the fibrous base material ranges from about 25 to about 70%, in other embodiments, from about 40 to about 65%, and, in certain embodiments, about 60 to at least 65%, by weight, total silicone-phenolic resin. After the fibrous base material is saturated with the resin, the fibrous base material is cured for a period of time (in certain embodiments for about 1/2 hour) at temperatures ranging between 300-400°C to cure the resin binder and form the friction material. The final thickness of the friction material depends on the initial thickness of the fibrous base material.

It further contemplated that other ingredients and processing aids known to be useful in both preparing resin blends and in preparing fibrous base materials can be included, and are within the contemplated scope of the present invention.

In certain embodiments, the resin mixture can comprise both the silicone resin and the phenolic resin which are present in solvents which are compatible to each other. These resins are mixed together (in preferred embodiments) to form a homogeneous blend and then used to saturate the fibrous base material. In certain embodiments, there is not the same effect if the fibrous base material is impregnated with a phenolic resin and then a silicone resin is added thereafter or vice versa. There is also a difference between a mixture of a silicone phenolic resin solution, and emulsions of silicone resin powder and/or phenolic resin powder. When silicone resins and phenolic resins are in solution they are not cured at all. In contrast, the powder particles of silicone resins and phenolic resins are partially cured. The partial cure of the silicone resins and the phenolic resins inhibits a good saturation of the base material.

In certain embodiments of the present invention, the fibrous base material is impregnated with a blend of a silicone resin in a solvent which is compatible with the phenolic resin and its solvent. In one embodiment, isopropanol has been found to be an especially suitable solvent. It is to be understood, however, that various other suitable solvents, such as ethanol, methyl-ethyl ketone, butanol, isopropanol, toluene and the like, can be utilized in the practice of this invention. The presence of a silicone resin, when blended with a phenolic resin and used to saturate the fibrous base material, causes the resulting friction materials to be more elastic than fibrous base materials impregnated only with a phenolic resin. When pressures are applied to the silicone-phenolic resin blended impregnated friction material of the present invention, there is a more even distribution of pressure which, in turn, reduces the likelihood of uneven lining wear. After the silicone resin and phenolic resin are mixed together with the friction modifying particles, the mixture is used to impregnate the fibrous base material.

Fig. 1 shows a schematic diagram of a friction material 10 having a fibrous base material 12 and filler or surface friction modifying materials 14 substantially interspersed within the fibrous base material 12.

INDUSTRIAL APPLICABILITY

The present invention is useful as a high energy friction material for use with clutch plates, transmission bands, brake shoes, synchronizer rings, friction disks or system plates.

The above descriptions of the preferred and alternative embodiments of the present invention are intended to be illustrative and are not intended to be limiting upon the scope and content of the following claims.